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History of rocketry in India

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Abstract

The Indian Space programme took birth on November 21, 1963, with the launch of Nike-Apache, an American sounding rocket from the shores of Thumba near Thiruvananthapuram on the west coast of India. From a family of operational sounding rockets known as the Rohini Sounding Rockets, India's launch vehicles have now grown up through SLV-3 and Augmented Satellite Launch Vehicle (ASLV) to the current gigantic satellite launchers, PSLV and Geosynchronous Satellite Launch Vehicle (GSLV). Though we had failures in the initial launches of SLV-3, ASLV and PSLV, these failures gave Indian Space Research Organisation (ISRO) a thorough and in depth understanding of the nuances of launch vehicle technology that later led to successful missions. An entirely new dimension was added to the Indian space programme when a space capsule was recovered very precisely after it had orbited the Earth for 12 days. The future for launch vehicles in ISRO looks bright with the GSLV MKIII, which is currently under development and the pursuit of cutting edge technologies such as reusable launch vehicles and air-breathing propulsion.
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1. Historical references

Rockets as weapons of war "flourished in India from at least the reign of Moghul Emperor Akbar (1556–1605)" (Winter, 1990). But the most well documented historical account of rockets as weapons refers to the exploits of the father–son combine of Hyder Ali and Tipu Sultan of Mysore in the late 18th century. Their rockets had a range of 2–3 km, which was considered 'outstanding' for those times. Though, Tipu could devastate the British Army with his rockets, he was ultimately killed in the war. The British captured hundreds of Tipu's rockets and transported them to England where they subjected them to modern methods of scientific analysis and improved the performance of the rockets. It was, however, the Germans who perfected the rocket as a weapon with their V-2, the most dreaded weapon of the World War II.

Just as the British took the rockets of Tipu, the Americans took the V-2 rockets as well as some of the best engineers of Germany to the US after the Allied victory in WW II. It was the Americans who first used the rocket for exploration of the Earth's upper atmosphere. Thus was born the "sounding rocket" in 1946.

2. The International Geophysical Year (IGY)-birth of space age

One of the most significant, globally coordinated scientific ventures was the International Geophysical Year (IGY) observed during the period July 1957–December 1958. This particular spot was chosen because the 11-year solar cycle was expected to reach its peak during that period. Post-World War II developments in rocketry for the first time made the exploration of space a real possibility; working with the new technologies,

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Soviet and American participants sent artificial satellites into Earth orbit. In successfully launching science into space, the IGY scored its greatest breakthrough. And in India, Vikram Sarabhai was the first to cash in on this breakthrough.

Jawaharlal Nehru, our first Prime Minister believed that modern science and technology were indispensable to solving the economic and developmental problems facing the country. Thus, after the launch of Sputnik-1 by Russians, Nehru's Government passed the Scientific Policy Resolution in 1958, which encouraged research and development in the fields of science and technology in India.

Consequently, in 1962, the Indian counterpart of Committee on Space Research (COSPAR), called the Indian National Committee on Space Research, INCOSPAR, was created under the chairmanship of Vikram A. Sarabhai. The main objective was to liaise with COSPAR and promote international cooperation in space research and explorations, and in the peaceful uses of outer space.

3. Reasons why Thumba was chosen

The following factors led to the establishment of the Thumba Equatorial Rocket Launching Station (TERLS) near Trivandrum (now Thiruvananthapuram).

In 1962, the Scientific and Technical Sub-committee of the United Nations Committee on the Peaceful Uses of Outer Space urged the creation of an International Equatorial Sounding Rocket Launching Facility. In the same year (1962), COSPAR proposed extensive synoptic sounding rocket programmes in meteorology, the ionosphere, solar activity, and the Earth's magnetic field. Specific studies had to be carried out on the magnetic equator, which has a high relevance in the investigation of ionosphere. Hence, a sounding rocket launching facility was established at Thumba, due to its proximity to the magnetic equator, under United Nations sponsorship. Dr. Sarabhai was also interested in the scientific study of the behaviour of cosmic rays near the magnetic equator.

3.1. Sarabhai, the man in a hurry

Once he got the official sanction, Dr. Sarabhai acted with lightning speed so that the very next year, on the November 21, 1963, the first sounding rocket took off from an obscure fishing village called Thumba near Trivandrum, the capital of the Kerala State, on the west cost of India. Thus was born the Thumba Equatorial Rocket Launching Station, the first seed of what later became the vast organisation called the Indian Space Research Organisation, ISRO.

The decade 1963–1973 was perhaps historically the most significant period in the evolution of ISRO. They were the crucial years during which the hard work of the scientists and engineers in ISRO laid the foundation on which the edifice of ISRO could be built.

3.2. The three-pronged approach

Sarabhai's focus was that space should be utilised for the benefit of mankind and for the development of the nation. With hindsight, it is easy to see his plan for the fledgling Indian space programme, especially with reference to sounding rockets. His was a three-pronged approach.

a. *Keep TERLS busy by regularly launching sounding rockets from foreign countries*. This provided hands-on experience to both scientists and engineers in designing payloads, conducting in-situ experiments, preparing sounding rockets and launching them safely. They also gained experience in designing and developing housekeeping equipment like telemetry systems and payload mechanisms like deployment systems, booms, etc.

b. *Launch the Centaure indigenisation programme*. This resulted in creation of Rocket Propellant Plant (RPP) and, subsequently, Rocket Fabrication facility (RFF) at Thumba. Invaluable insights into the design of propellant plants and handling all phases of propellant production ensuring safety were gained.

c. *Encouraging indigenisation efforts in all branches of rocketry*. The various engineering teams were encouraged to take initiative in designing and developing indigenous systems in all branches of rocketry.

4. The Indian sounding rockets

These are known by the generic name: Rohini Sounding Rockets. They were developed with two major objectives. The first objective was to meet the requirements of conducting experiments on upper atmosphere, ionosphere and near space. The second objective was to acquire competence in the basic aspects of rocketry, as stepping-stones to develop the more powerful and complex satellite launch vehicles. To give a glimpse of those efforts, we give below brief descriptions of two of the designs.

4.1. RH-75

The very first truly Indian sounding rocket was the RH-75, the RH standing for Rohini and 75 for the

diameter of the rocket in mm. The materials needed for the motor was assembled and the motor was ground tested and subsequently flight-tested. The development of motor gave useful inputs towards: (a) design and performance, (b) propellant charging techniques, (c) test stand design and testing techniques, and (d) flight tests.

But, RH-75 was not, strictly speaking, a Thumba rocket! Two of its most crucial components, viz., the motor case and the propellant, were made outside Thumba. The next steps taken were to:

a. try in-house propellant formulations,
b. fabricate hardware in Thumba,
c. try staging (i.e., rocket with more than one stage) and,
d. go for larger and more powerful sounding rockets capable of taking heavier payloads to greater altitudes.

4.2. RH-125

The important inputs derived from this programme were:

a. improvement in propellant formulation and processing,
b. handling and charging of flexible propellants grains,
c. staging and stage separation techniques.

Besides providing the wherewithal for space scientists to conduct a variety of experiments, the Rohini Sounding Rocket programme laid a robust foundation for the launch vehicle development in ISRO.

5. SLV-3

Sounding rockets provided the technological capability in solid propellants. Applying these to the larger and multi-stage rocket systems, in early 1970s, efforts were initiated for the development of India's first Satellite Launch Vehicle SLV-3. SLV-3 was a four-stage vehicle using solid propulsion. It was a fully indigenous effort, which gave insight to the major technologies involved in rocketry. To assemble and test long size solid propulsion systems, integration and launch of the vehicle, considerable area isolated from human inhabitation was required and for this purpose a launch station at Sriharikotta was developed as a major facility with associated infrastructure. The first attempt to launch SLV-3 in 1979 was not successful due to minor malfunction of control thruster. However, in the second launch in 1980, the Rohini satellite was injected into orbit, making India one of the six nations in the world to develop this technology. The three successful launches of SLV-3 during 1980–1983 provided the required insight into design and development of multi-disciplinary launch vehicle systems, mission management, launch operations and establishing, tracking, telemetry, telecommand networks.

6. ASLV

SLV-3 was a tiny launch vehicle with a very low payload capability. Hence, many of the vital technologies absolutely necessary for orbiting application satellites, such as strap on technology, closed-loop guidance, yaw maneuvering bulbous heat shield, vertical integration with the associated infrastructure, liquid propulsion systems, etc could not be tried out in SLV-3. What India needed was to launch vehicles capable of putting bigger spacecrafts into the sun synchronous Polar or GTO orbit!

If ISRO were to vault straight from SLV-3 to PSLV a lot of scaling up in size and using a host of hitherto unproven technologies had to be done, with a lot of budget implications. Hence, a less expensive alternative, which could accommodate most of the technologies listed above and at the same time, make use of the modules already proven in the SLV-3 was identified—the Augmented Satellite Launch Vehicle (ASLV). Except for liquid propulsion and cryogenic systems, ASLV could be used as a test bed for proving the new technologies ISRO needed for its future vehicles. The 150 kg payload capability also could be effectively utilised to carry out scientific experiments in space. Thus ASLV, proved to be, an ideal "technological bridge" between the SLV-3 and the PSLV!

The first developmental flight of ASLV was a failure. It was due to the non-ignition of the first stage motor due to suspected failure in the ignition chain. The second flight also failed due to certain lacunae in the control during the transition from zero-stage to first-stage regime. But, ISRO used these failures as stepping-stones to success! The major contribution of ASLV experience was that it enabled a better understanding of the complex atmospheric regime of flight considering control–structure interaction, implementation of onboard real-time based decision making of mission management and closed-loop guidance for better tolerance in satellite injection conditions. With two successful launches of ASLV during 1992–1994, all the objectives of this program was achieved.

7. PSLV

Even when the development of ASLV was going on, ISRO took the challenging task of developing PSLV

for launching 1 ton class of operational remote sensing satellites into Sun Synchronous Polar Orbit (SSPO). The vehicle configuration was finalised after a lot of studies and iterations. It consisted of a nominal 125 ton solid propellant booster with 37.5 ton (nominal) liquid propellant second stage, a suitably sized solid third stage and a liquid fourth stage. The first stage had a configuration to accommodate upto six strapons essentially derived from the first stage of SLV-3 with minimum essential modifications.

The final liquid stage was inducted to achieve precise injection conditions for the altitude and orbital inclination parameters.

7.1. It is different

PSLV provided a quantum jump in developments in terms of size and technology. PSLV is the first vehicle of ISRO to use liquid propellants for primary propulsion. The avionics, too, went through radical changes compared to what was in SLV-3 and ASLV. It also led to the development of much larger vehicle integration and launch facilities such as mobile tower, launch control centre, tracking, telemetry and telecommand facilities and large infrastructure development with increased participation of the Indian industry. The requirement of large scale liquid engine development, testing and integration called for creating a liquid propulsion testing complex at Mahendragiri during the 1982–1988 time frame.

All the PSLV systems functioned well in the first flight conducted in 1993, but still the mission could not succeed in injecting the satellite into orbit due to a software implementation error. This led to strengthening further the ground simulations, additional testing of the vehicle hardware and software systems to its fullest capabilities prior to launch. All the further flights of PSLV were successful.

PSLV is the first vehicle to launch three satellites at a time, the first to be deployed for both GTO and SSO missions, and also the first to launch foreign satellites. Chandrayaan-1, which represents India's foray into the domain of planetary exploration, is also being launched by PSLV.

8. GSLV

Concurrent to the development of PSLV, ISRO initiated the challenging task of developing the Geosynchronous Satellite Launch Vehicle—GSLV for launching 2 ton class of operational communication satellites into GTO. GSLV is configured with three stages, employing solid, liquid and cryogenic propulsion modules for its stages. Keeping the pedigree of already developed stages and in order to reduce the overall development cost and schedule, the PSLV modules were maximally utilised for the first two stages of GSLV. The major technology developments that have taken place during this project phase are technologies related to cryo engines. Initially a procured cryogenic engine from Russia was used for the upper stage, though the related avionics was totally indigenous. A state-of-the-art second launch pad also was developed and established during this time frame for GSLV and future heavy lift launches. GSLV, which lifted off with a payload of 1540 Kg in its first development flight, has now reached a payload capability of 2200 kg.

Indigenous cryogenic engine has now been qualified along with the associated avionics systems, through a series of ground tests and stage level tests.

The fourth flight of GSLV during 2006 was a failure due to premature shut down of one of the strap on liquid engines. However, this discrepancy was corrected and a successful mission achieved in September 2007.

9. SRE

A major milestone achieved by ISRO was the successful recovery of the Space Capsule (SRE-1) after orbiting in space for 12 days. It demonstrated our capability to conduct microgravity experiments in an orbiting spacecraft and bring it back to Earth, thus proving the technology of de-orbiting, de-boosting and recovering objects from space. The SRE-1 has provided valuable inputs for the design of future reusable launch vehicles and human space missions.

10. Looking back

ISRO has succeeded in achieving the objectives of Dr. Vikram Sarabhai in the last three decades. Today India has well structured application programmes meeting the needs of the country in remote sensing, communications, broadcasting, teleeducation, telemedicine, weather monitoring, disaster management and many other areas. India also implemented its space programme with a shoe string budget over the years. The approach taken by Indian Space programme highlights the bold and imaginative adoption of new technologies to accelerate the process of development in the country. It is also pertinent to add that the Indian space activities are more tailored to meet peculiar problems of a developing country like India.

11. The future

GSLV-MK III, which has a capability of placing a 4 ton class payload into the Geosynchronous Transfer Orbit, is the next major milestone for ISRO. The realisation of GSLV-MKIII within the next two years would enable India to meet the requirements of heavier communication satellites with more power and capability.

Low cost access to space is one of the major requirements for future space missions. Towards this, ISRO has initiated development work in cutting edge technologies such as reusable launch vehicles and air-breathing propulsion systems. Human space mission is also one major activity planned for the next decade.

With GSLV MK III, Chandrayaan, our initial attempts at air-breathing propulsion, RLV, etc the future of launch vehicle technology in ISRO looks bright.

12. Conclusion

From a humble entry to space arena, India leap frogged to the front ranks of countries engaged in launch vehicle technology. This paper explains in brief the history of launch vehicle technology developments in India starting from the development of tiny sounding rockets, through SLV-3 and ASLV to the operationalisation of gigantic launch vehicles like the PSLV and GSLV. The entire programme has gone through trials and tribulations and stood the test of time. This programme is one good example as to how a developing country can utilise the advanced technologies for the development of the nation and thus benefit the common man.

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